

jakieś wady. Na przykład zdolność adsorpcyjna zeolitów jest słaba i wykazują niską skuteczność w usuwaniu barwników. Węgiel aktywny też ma pewne wady ponieważ przenosi barwniki tylko z fazy ciekłej do fazy stałej. Tak więc badania możliwości zastosowania nowych materiałów o dobrej zdolności adsorpcyjnej do usuwania barwników ma nadal kluczowe znaczenie.

Nowymi materiałami, które mogą być skuteczne w usuwaniu barwników są biowęgla. Biowęgiel jest węglową stałą pozostałością po obróbce termicznej biomasy bogatej w węgiel, w procesie pirolizy prowadzonej w niskiej temperaturze. Wzrost zainteresowania biowęgla jest w dużej mierze oparty o dwie odrębne korzyści: po pierwsze, produkcja biowęgla może zrównoważyć emisję gazów cieplarnianych, ponieważ magazynuje węgiel w stabilną formę. Po drugie, biowęgiel jest skutecznym, i tanim adsorbentem przyjaznym dla środowiska, co wiąże się z jego stosunkowo dużą powierzchnią i obecnością licznych powierzchniowych grup funkcyjnych. Badań nad zastosowaniem różnych biowęgla jako adsorbentów w oczyszczaniu wody z metali ciężkich, barwników, farmaceutyków jest coraz więcej. Istnieje kilka prac dotyczących badania procesu adsorpcji barwników na biowęglach wytworzonych z sosnowych trocin, łupin pistacjowych. Badania te wykazują wysoką efektywność procesu adsorpcji. Jednak wydajność procesów adsorpcji różni się pomiędzy sobą, wynika to ze stosowania różnego typu materiałów powstałych w odmiennych warunkach pirolizy. Aby dokładnie ocenić wpływ adsorpcji biowęgla na usuwanie barwników z roztworów wodnych konieczne jest utworzenie bazy danych adsorbentów wyszczególniające właściwości biowęgla uzyskanego z różnych źródeł i powstałego w różnych warunkach. Baza stanowiłaby cenne wsparcie teoretyczne dla rozwoju i powszechnego zastosowanie biowęgla do uzdatniania wody.

Głównym celem pracy jest zbadanie zachowania i mechanizmu barwników (błękitu metylenowego, czerni erichromowej) na biowęglach z odpadów komunalnych, w szczególności: (1) określenie wpływu następujących czynników: dawki biowęgla, pH roztworu, czasu sorpcji i początkowego stężenia barwników; (2) wyznaczenie izoterm sorpcji.

Badania wykazały, że biowęgla są obiecującymi adsorbentami do usuwania barwników z roztworów wodnych. Biowęgiel z kompostu w dawce 0.15 mg/g może prawie całkowicie odbarwić roztwór błękitu metylenowego o stężeniu wynoszącym 25 mg/g ($R=98\%$). Adsorpcję równowagową uzyskano po 120 minutach, przy pH=6.

SEWAGE SLUDGE USAGE IN PRODUCTION OF ECO-EFFICIENT CONSTRUCTION MATERIALS

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Worldwide, sewage sludge is generated in great quantities in municipal wastewater treatment plants. Due to the rapid industrialization and urbanization of developing countries, the amount of wastewater which should be treated recently has increased substantially. The amount of produced sewage sludge significantly increases along with the number of wastewater treatment plants and the efficiency of sewage treatment processes with a removal of carbon compounds and biogenic substances. Sewage sludge often threatens the natural environment; hence, it has to be processed in an appropriate way. The sewage sludge deposition in landfills and its application in

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agriculture have been limited by the regulations issued by the European Union. Primarily, this is because sewage sludge contains refractive pollutants, unstable pathogens and heavy metals that may be a potential hazard for human health and natural environment. Heavy metals are still dangerous after stabilization through the standard treatment process, e.g. by methane digestion. Therefore, agriculture application and landfilling of sewage sludge may no longer be performed and alternative methods of its disposal have to be sought. As a result, valuable raw materials can possibly be recovered from potentially harmful materials. Utilization of wastes and the usage of recycled materials in construction applications have been a common practice and have increased globally over the last decades. When appropriately processed, they may be applied in heat and energy recovery as well as construction industry. The practical application of sewage sludge in the production of different building materials, including light expanded aggregates, lightweight aggregate-concrete and ceramic materials, is described in literature. Unfortunately, sewage sludge frequently exhibits high moisture absorptivity as a result of its lightweight and porous structure. It causes a serious issue related to the composition of the lightweight aggregate-concrete mixtures and the ready-products. Essentially, it affects the heat flow process by increasing the thermal conductivity of materials when aggregates absorb water. The type and distribution of pore networks as well as their connection with the aggregate surface constitute important features for the production of lightweight concretes. When the cement mortar has unsuitable viscosity, the differences between volumetric densities of lightweight aggregates and covering them with cement mortar cause the aggregates to flow out. Several procedures can be applied to avoid the unfavorable phenomenon of subtraction of the water required for the hydration process by lightweight aggregate. One of the methods involves initial wetting to protect the aggregates against autogenic contraction. Covering the aggregates with cement grout or ceramic shell, which provides lower water absorptivity of the aggregates, increases the density of aggregate particles and, thus, essentially influences concrete strength, represents another possible solution. Impregnation of aggregates, closing air gaps and preventing water penetration with constant adherence of particles to the cement matrix, constitutes an alternative approach. Hydrophobization of the aggregates and mortar reduces capillary water absorption; however, the pores or capillaries are still open, which enables free vapor permeability. Conducting hydrophobization during lightweight block manufacturing would eliminate the phenomenon of excessive moisture during exploitation of building objects. Additionally, it would provide considerable protection against the transport of saline solutions into the brickwork, thus preventing material destruction due to the multiple freezing and thawing cycles in winter and the phenomenon of dissolved salt crystallization. In addition, the materials containing salt exhibit higher moisture than the materials that are free from salts.

The use of the ashes from sewage sludge incineration in the production of environmentally efficient building materials is another interesting approach. Incineration of sewage sludge is one of the commonly used methods of managing sewage sludge generated in large wastewater treatment plants, which are unsuitable for use in agriculture or reclamation of degraded areas due to, e.g. increased content of heavy metals. Thermal management of sludge enables to obtain heat energy, and it can decrease the energy consumption for the production of pozzolanic materials by using ash from the thermal management process. Appropriate technical procedures enable using potentially harmful waste materials from the sewage sludge incineration – which are considered to carry a high environmental risk – for manufacturing cement mixtures and reducing the environmental burden by avoiding the storage of waste, i.e. resulting ash. Other environmental aspects pertaining to the preparation of standard cement mixtures are also of high importance,

including the emission of greenhouse gases, predominantly CO₂. The CO₂ emission results from two aspects of cement production. The first pertains to the chemical reaction involved in the production of clinker, which is the main component of cement, since limestone undergoes decomposition through the addition of heat. The second source of emissions is the combustion of fossil fuels used for heating up the raw ingredients of clinker to the melting temperature. Due to the high carbon footprint of cement production, various types of mineral admixtures were tested as prospective substitutes of Portland cement. These substitutes include by-products of iron, silicon and ferrosilicon alloys production, as well as the waste products from coal combustion in thermal power stations, in addition to the above-mentioned ash from sewage sludge combustion. Therefore, through the appropriate application of the circular economy principles, many problems related to the negative impact of waste generated in plants of various branches of the economy, including water and wastewater management, can be solved. Combining lightweight aggregate utilizing sewage sludge with cement mixtures prepared using ash from incineration of sewage sludge can yield “green product” in the form of ready-to-use lightweight aggregate-concrete blocks.

To conclude, the application of appropriately transformed waste (sewage sludge) allows reduce energy consumption and decrease the greenhouse gas emissions resulting from the production of Portland cement. Thus, the developed blended cements, mortars and concretes as well as blocks with sludge containing lightweight aggregate can be considered as “green building materials”, also referred to in the literature as eco-efficient construction materials.

MATHEMATICAL MODELING OF STORMWATER NETWORK AND COMBINED SEWER NETWORK ACCOUNTING FOR SENSITIVITY AND UNCERTAINTY OF THE ESTIMATED PARAMETERS

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Negative changes in the stormwater system operation are caused by numerous factors, including on-going urbanization, involving increased share of impervious areas in urban catchments, as well as climate change affecting the amount of stormwater. These factors also impact the operation of stormwater overflow and frequently deteriorate the water quality in receivers. These phenomena occur due to the large runoff volume which increases in a short period of time, the great amount of pollutants that are leached from the atmospheric air and flushed from the catchment surface, as well as leaching of sediments deposits in channels. Another issue caused by the afore-mentioned factors involves higher frequency of stormwater floodings in urban catchments, as well as greater range of flooding, and depth of the overflowing stormwater. These factors hamper the functioning of urban infrastructure (road, sanitary, telecommunications), causing economic losses and lowering the life standards of urban residents. By preparing the plans of sustainable green infrastructure development, in addition to appropriately selected and located retention tanks, the unfavorable phenomena can be counteracted to reduce their magnitude as well